Fish Community Dynamics in Saginaw Bay: Trends from 1970-2008

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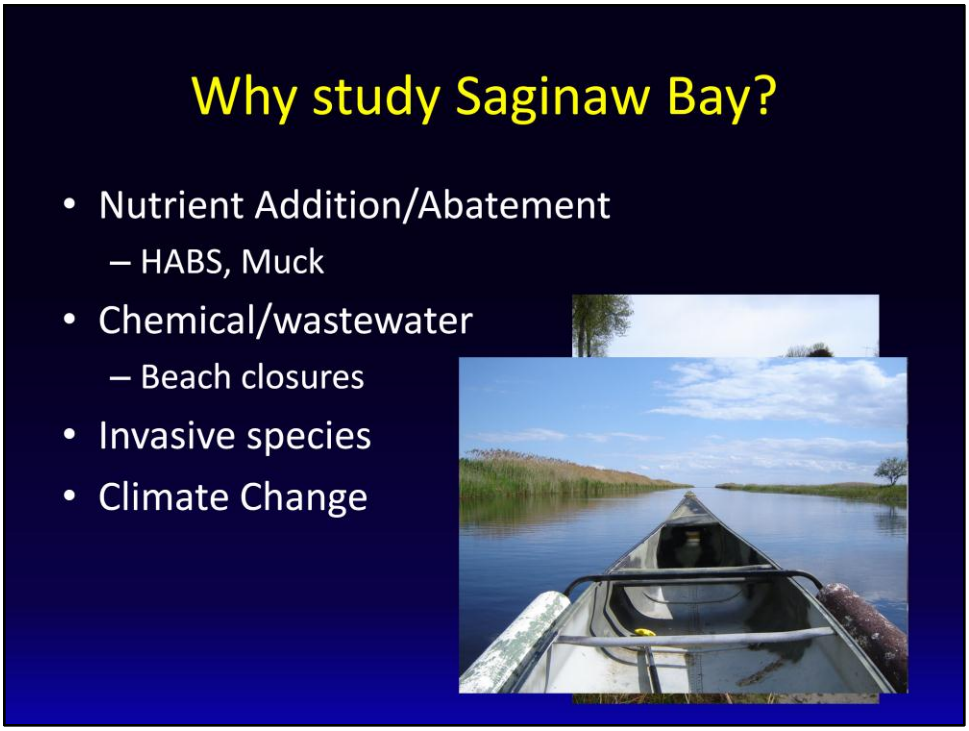
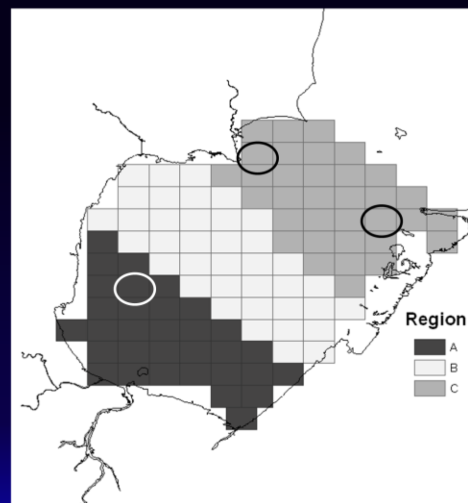


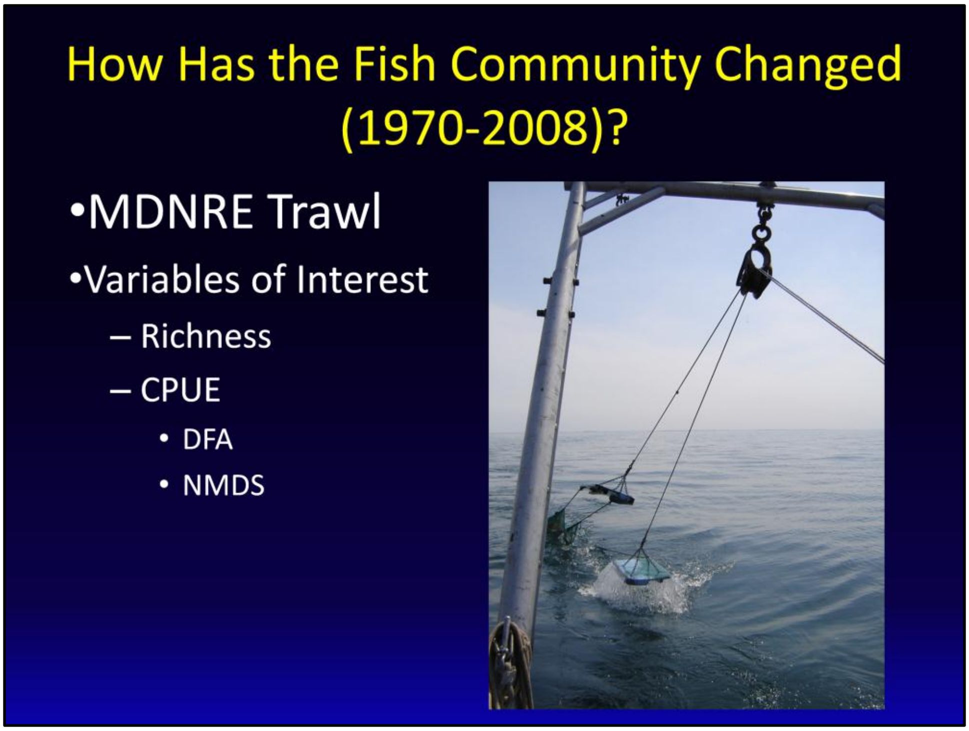
Saginaw Bay has experienced numerous stressors throughout the last century and more. These include nutrient loading, followed by nutrient abatement measures, chemical degradation (e.g., dioxins), and the invasion by numerous species, including fish (carp, round goby), plants (phragmites), and dreissenid mussels. These changes have had complex impacts on the Saginaw Bay ecosystem that complicate interpretations of changes in the fish community.

MIDNRE Fall Trawl Surveys

- Conducted in the fall
  - 1970-present
- 3 index stations + random grids
- Variable # of trawls
  - 13 to 84



Analyzed changes in the Saginaw Bay fish Community using data from the Michigan DNRE long-term fall trawl surveys, conducted from 1970-present in the inner portion of Saginaw Bay. Grids were randomly sampled annually (circled= the index stations that we sampled fairly regularly throughout the time period). However, the number of trawls conducted varied considerably throughout this time period.

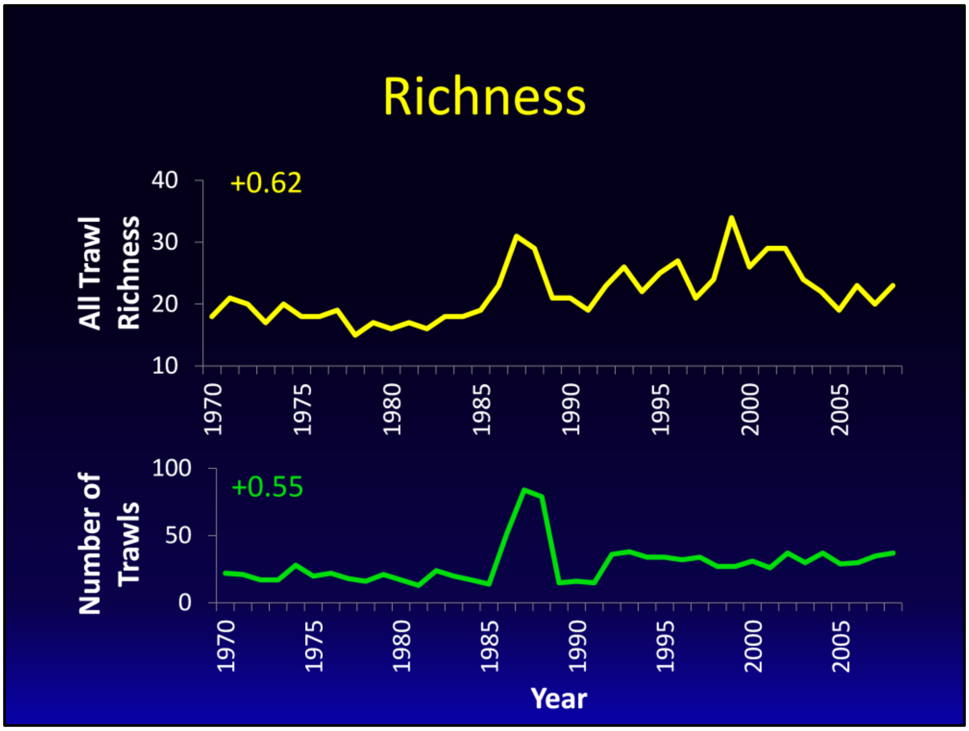


Variables that we were interested in included species richness and catch per unit effort (CPUE; #/min trawl). CPUE was analyzed using two different methods.

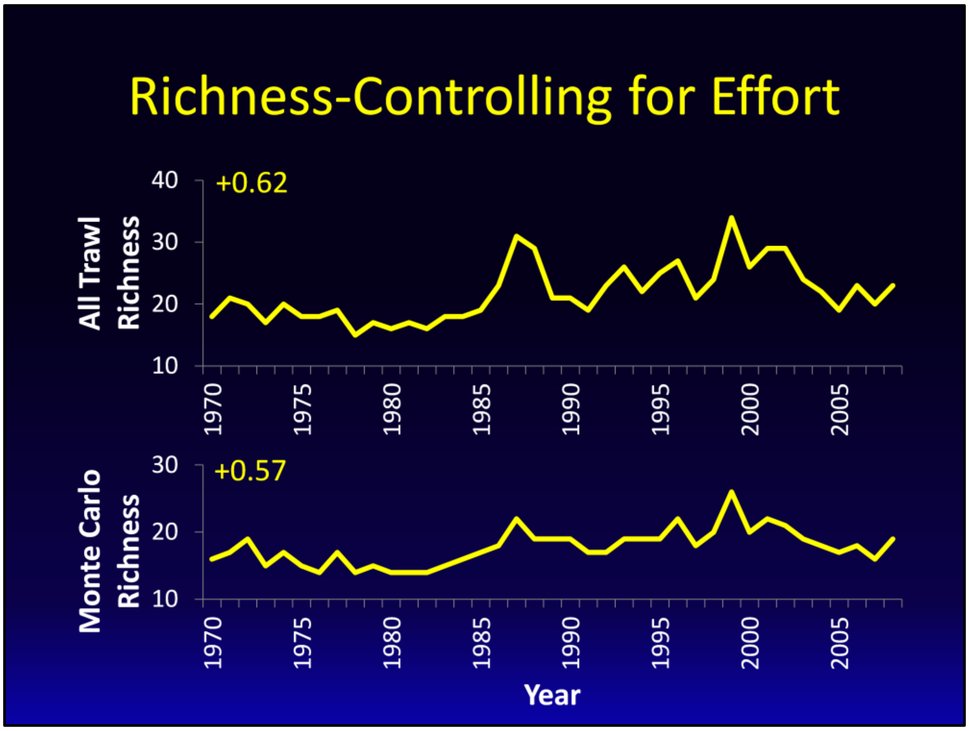
How Has the Fish Community Changed (1970-2008)?

- MDNRE Trawl
- Variables of Interest
  - Richness
  - CPUE
    - DFA
    - NMDS

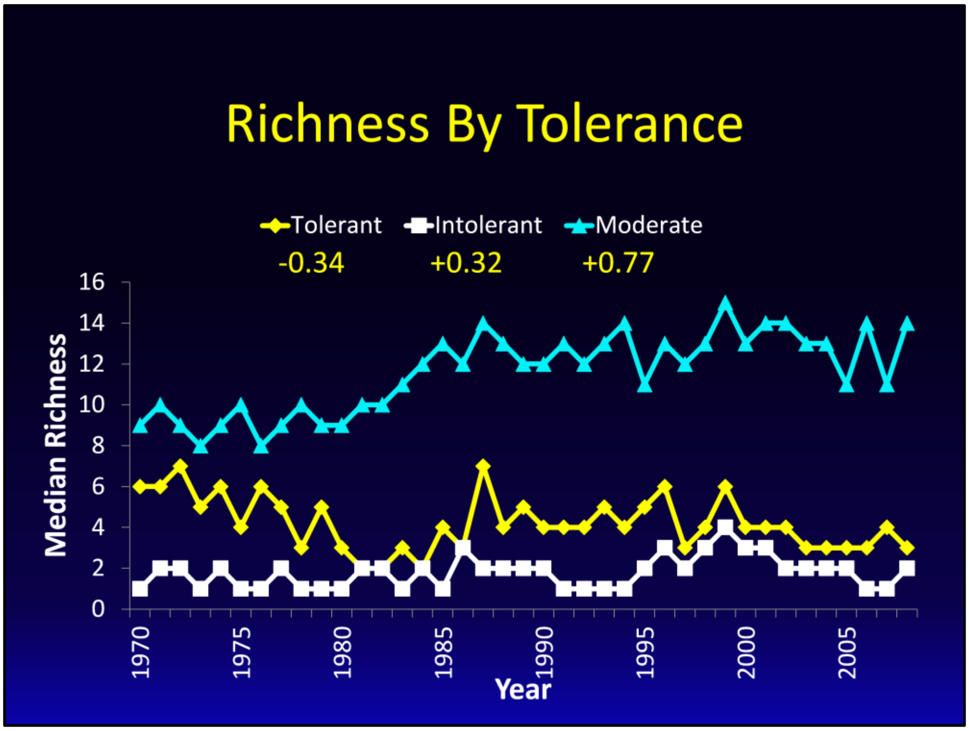
Go over richness first.



The top figure shows species richness over time if we count all species caught in all trawls. However, there has been variable effort, as indicated by the bottom figure. The bottom figure shows the number of trawls over conducted over time. The two numbers indicate the spearman's rho value for a rank correlation (Spearmans) conducted between richness and time and # trawls and time. Both are significant and positive. We therefore used a Monte Carlo simulation to determine if the increase in richness was due to the increased effort over time or due to an increase in the numbers of fishes captured.



Top figure shows the previous richness panel, uncorrected for richness. The bottom panel shows the median richness based on 10 trawls randomly selected 1000 times from a Monte Carlo simulation. While the rho value has declined (0.57) and the number of species has also declined, there still is a significant increase in richness over time (although there appears to be a slight decline since 2000).

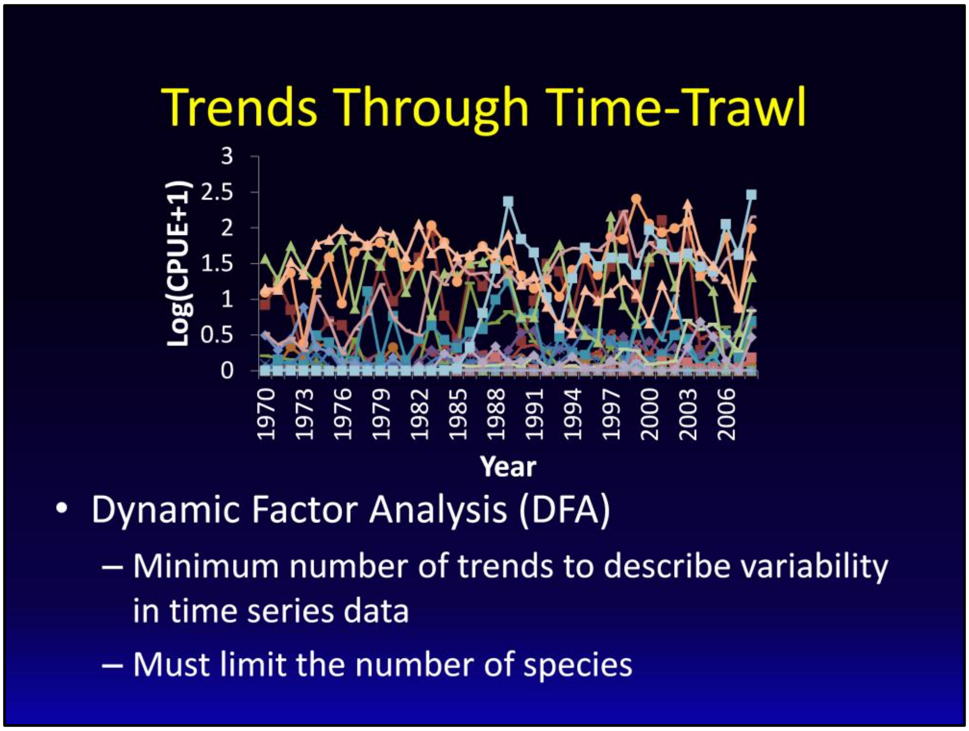


We can also look at how richness has changed within tolerance groups (tolerance to eutrophication) using Monte Carlo simulations. The figure shows median richness of tolerant, intolerant, and moderately tolerant species richness. All are significantly correlated with time; tolerant richness has declined (rho= -0.34) while intolerant and moderately tolerant species richness has increased (rho= +0.32 & +0.77, respectively).

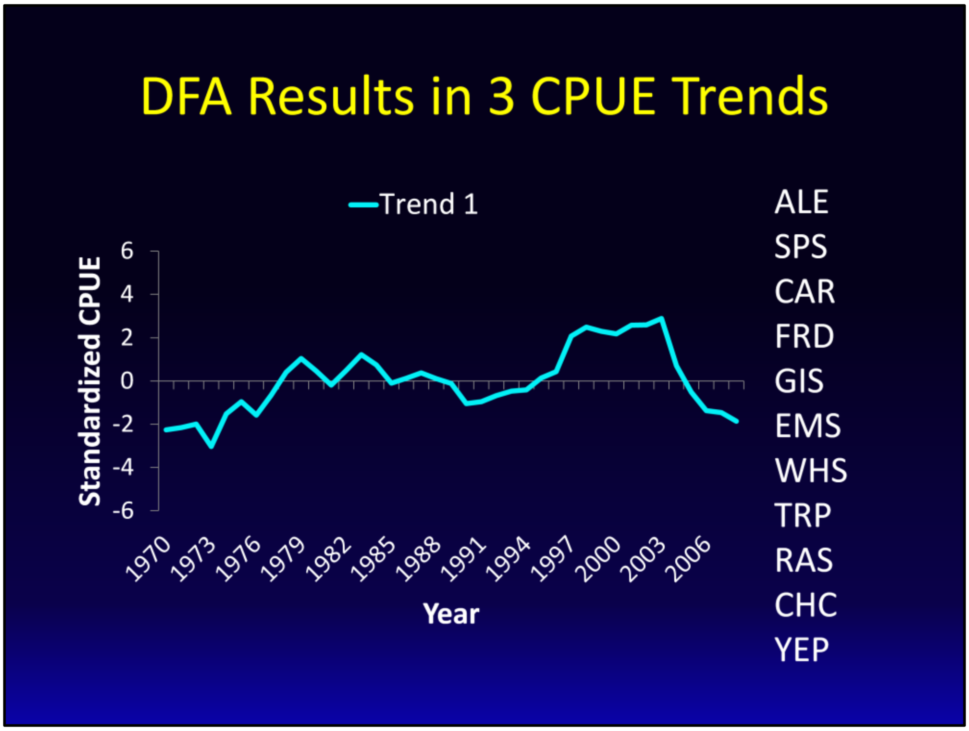
How Has the Fish Community Changed (1970-2008)?

- MDNRE Trawl
- Variables of Interest
  - Richness
  - CPUE
    - DFA
    - NMDS

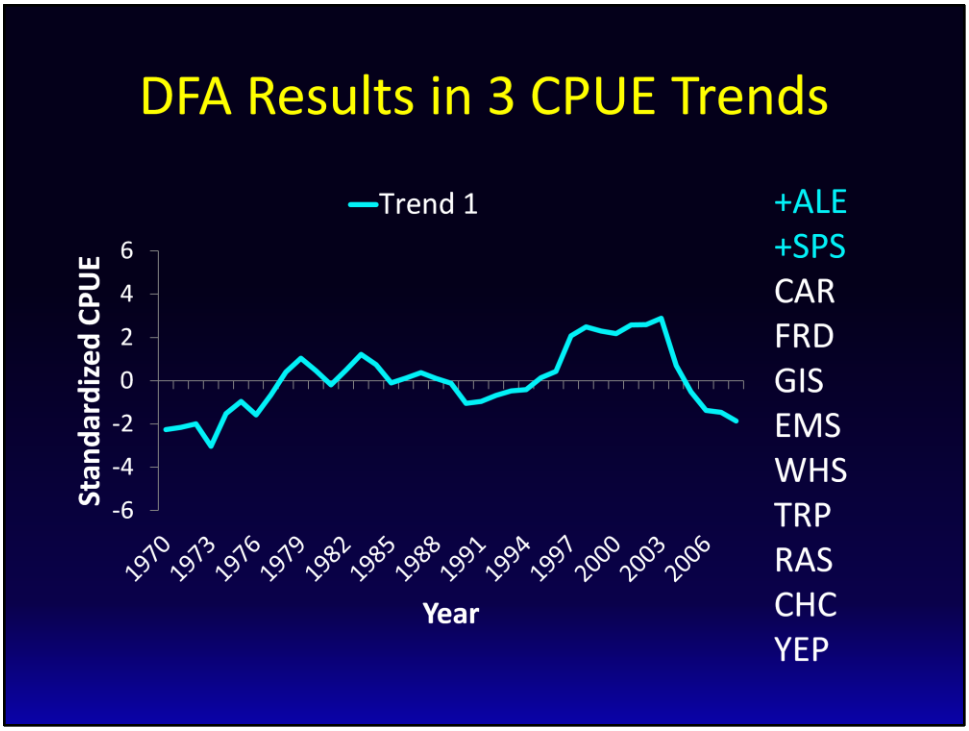
Now we will look at how CPUE has changed in the bay, starting with Dynamic Factor Analysis (DFA).



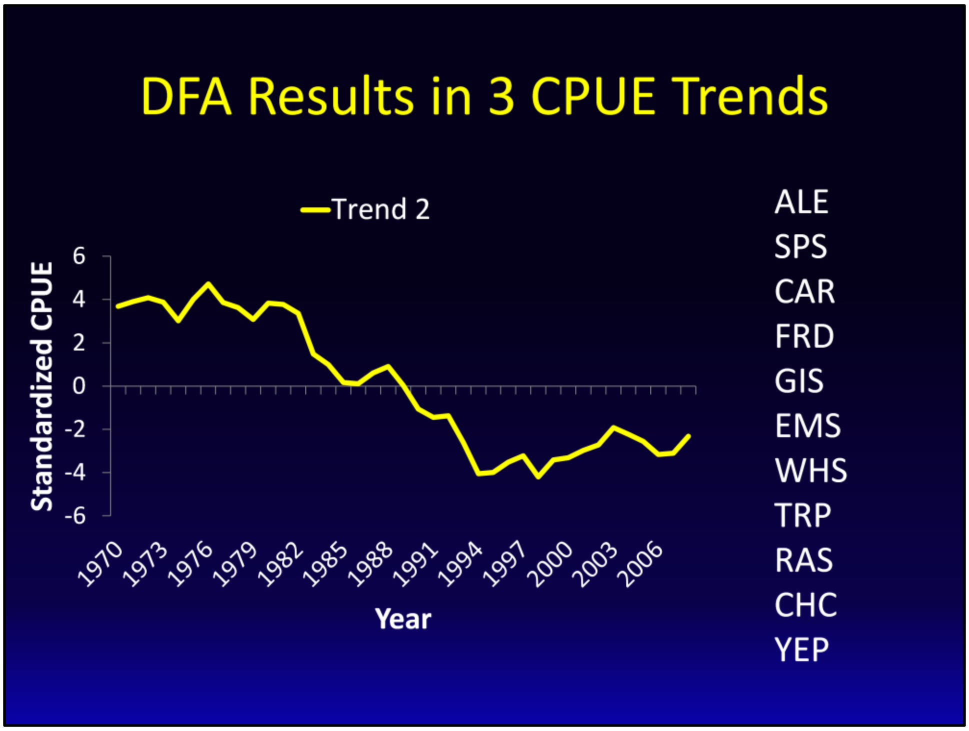
CPUE (log(CPUE+1)) trends through of the more common species captured in fall trawl surveys. The purpose of this figure is to show how difficult it is to determine changes in CPUE through time for a large community data set. Dynamic Factor Analysis (DFA) is a statistical technique designed for analyzing long-term time series data. The purpose of DFA is to describe trends through time using a minimum number of trends (i.e., are all species increasing or decreasing or are some increasing while others decline). The technique is useful, but requires that the number of species included in the analysis be limited. We chose at 90% cutoff. Thus, species were not included in the analysis if there were captured in less than 90% of the trawled years.



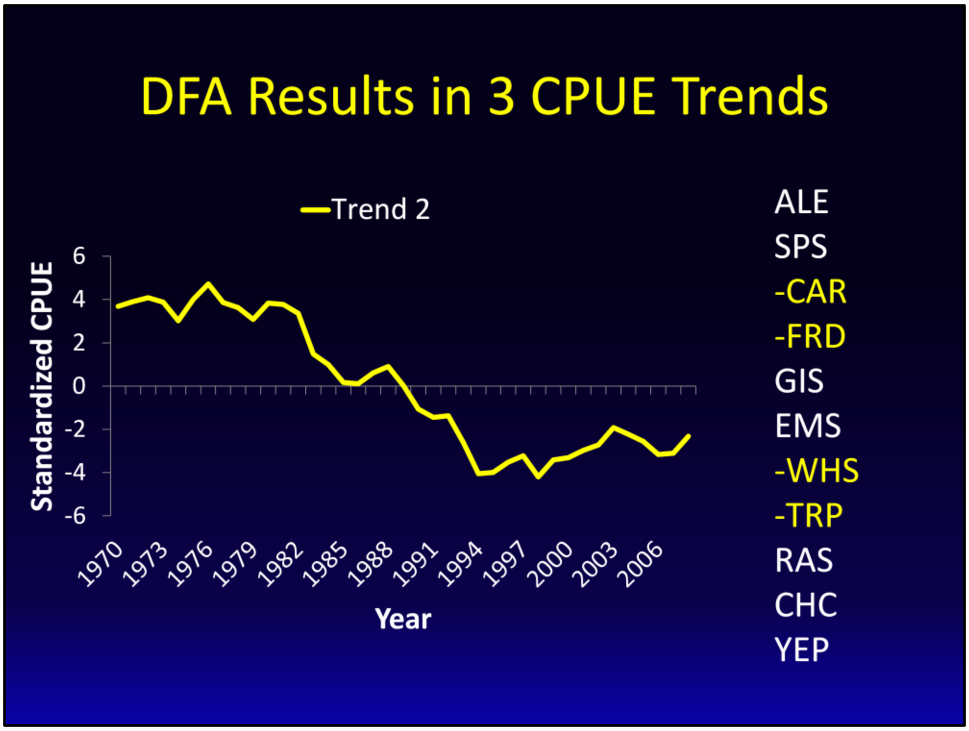
This shows the results of the DFA. The best DFA, as identified by AICc, was one of 3 trends. This means that the variation in the CPUE data from the 11 species listed on the left that were included in the analysis were adequately described by 3 trends. The figure shows the first trend, with standardized CPUE on the Y axis. Values less than zero indicate CPUEs below the time series mean while values above the zero indicate CPUEs above the time series mean. This first trend shows increasing CPUE throughout the time series, with a slight decline in the late 80s and a pretty large decline starting in about 2003.



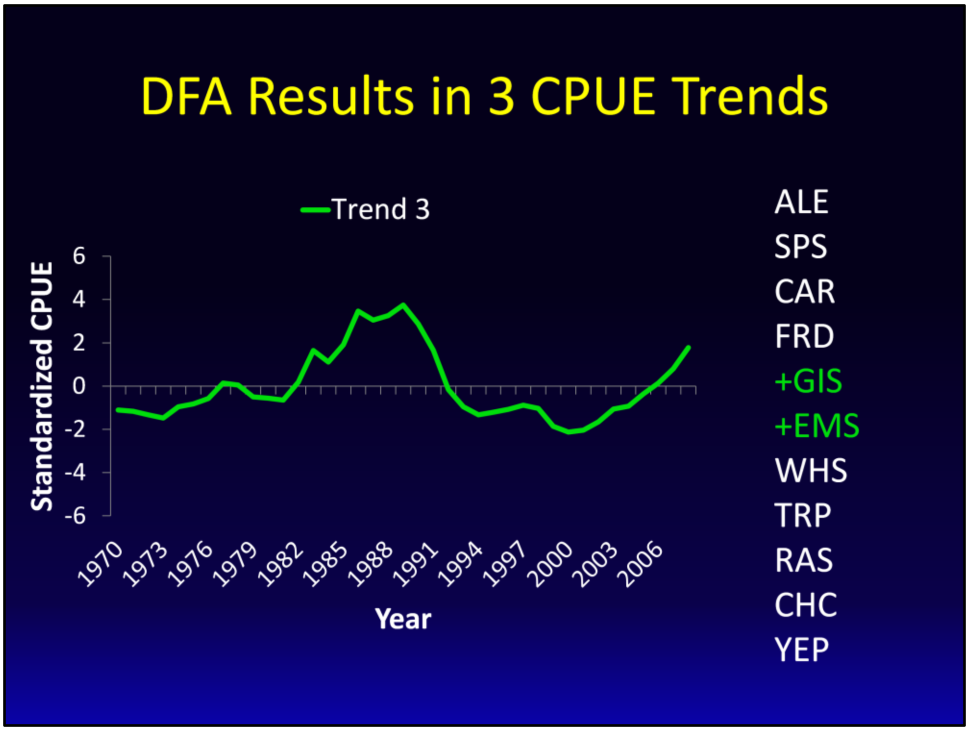
Species highlighted blue are significantly related to this trend. In this case, alewife and spottail shiner are positively related to this trend.



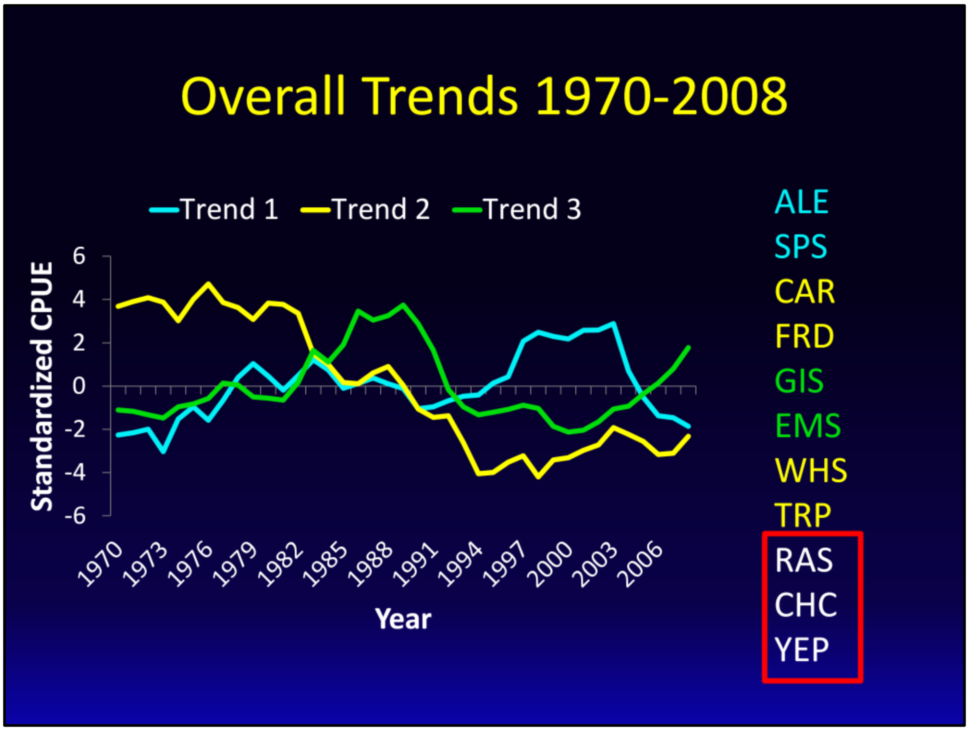
This shows the second trend as determined by DFA. It is one of declining CPUE until the mid-90s, when CPUE increases slightly.



Carp, freshwater drum, white sucker, and trout-perch are significantly related to this trend (shown in yellow), but they are negatively related. This means these species are following the opposite of this trend (low CPUEs in the 1970s, peaking in the mid-1990s).



The last trend appears to be cyclical, with a peak in CPUE in the late 80s and early 90s, and what appears to be another peak at the end of the time series. Gizzard shad and emerald shiner are positively related to this trend.



The three fish in the red box (rainbow smelt, channel catfish, and yellow perch) were not previously discussed. They were related to multiple trends, but essentially rainbow smelt and channel catfish have had fairly stable CPUEs during the time series while yellow perch CPUE has declined throughout the time series.

How Has the Fish Community Changed (1970-2008)?

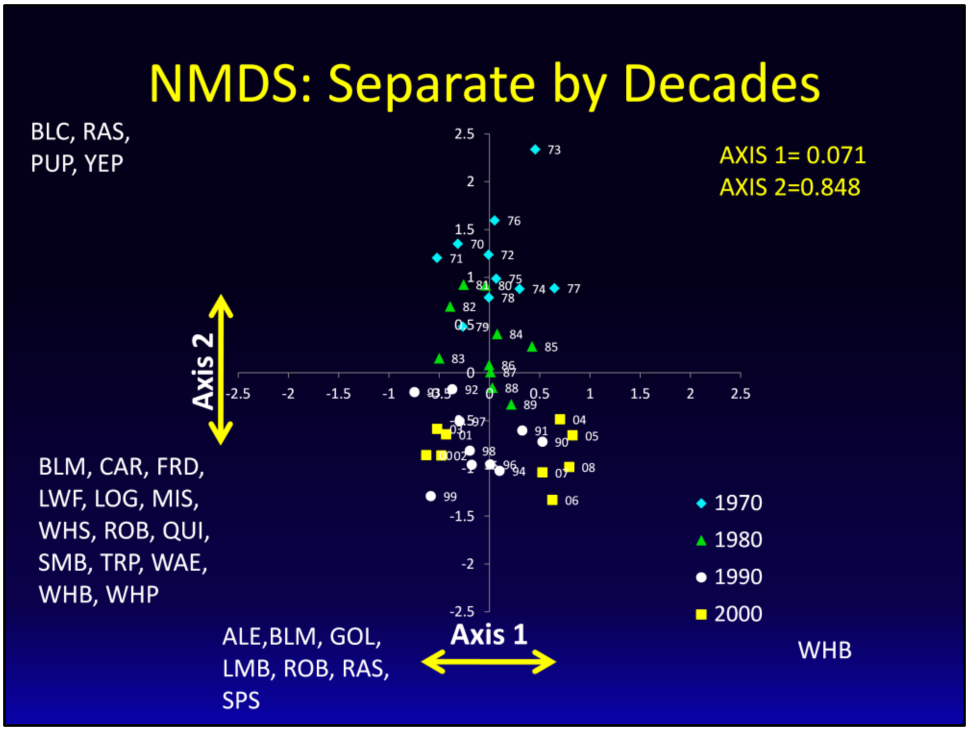
- MDNRE Trawl
- Variables of Interest
  - Richness
  - CPUE
    - DFA
    - NMDS

Now we will analyze CPUE using another statistical technique, Nonmetric multidimensional scaling (NMDS).

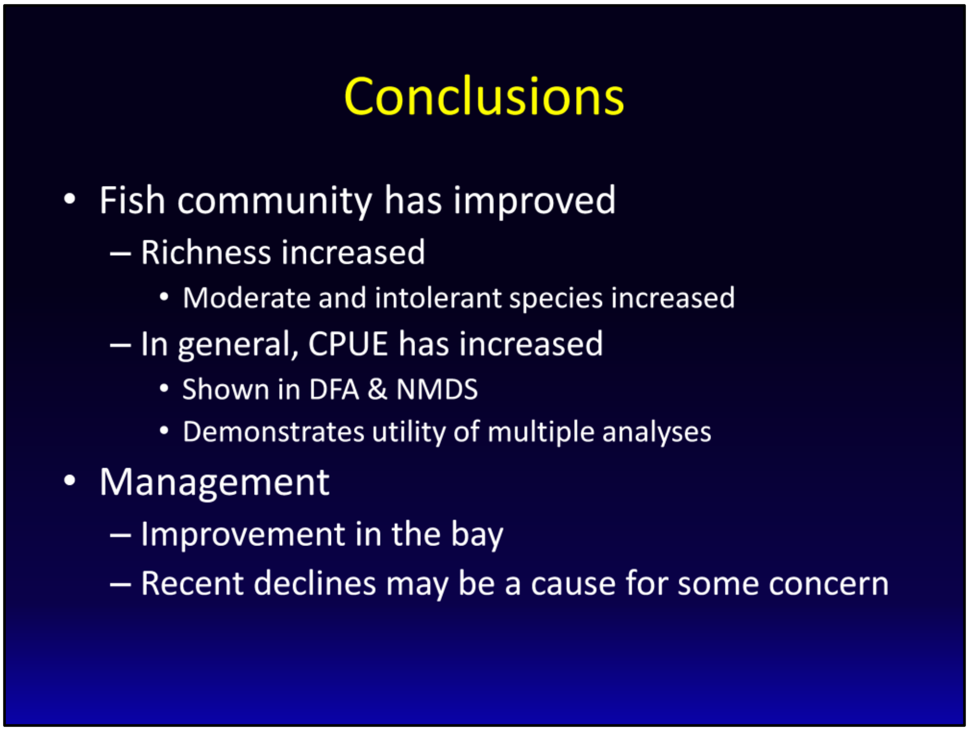
Ordination

- Nonmetric multidimensional scaling (NMDS)
  - Ordination technique
    - Similar to PCA
    - Purpose: Look for relationships in complex data sets
  - Advantages
    - No normality assumptions
    - Nonlinear relationships
    - Distance-preserving
    - Include more species than DFA

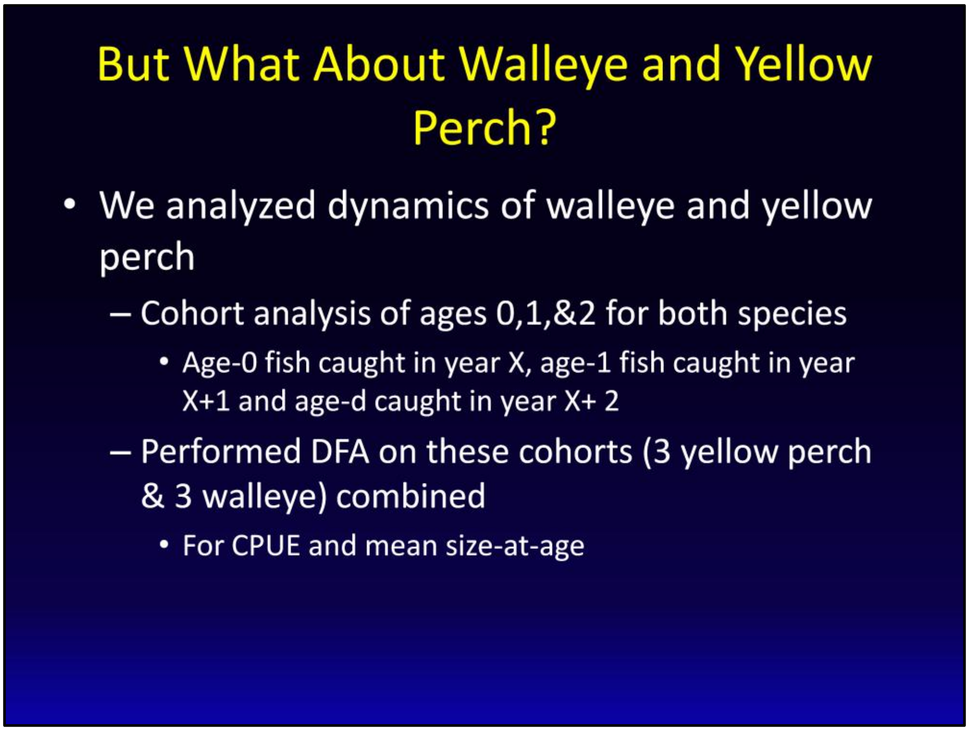
The biggest advantage for us using this technique is that we can include more species than in DFA and there are no normality assumptions.



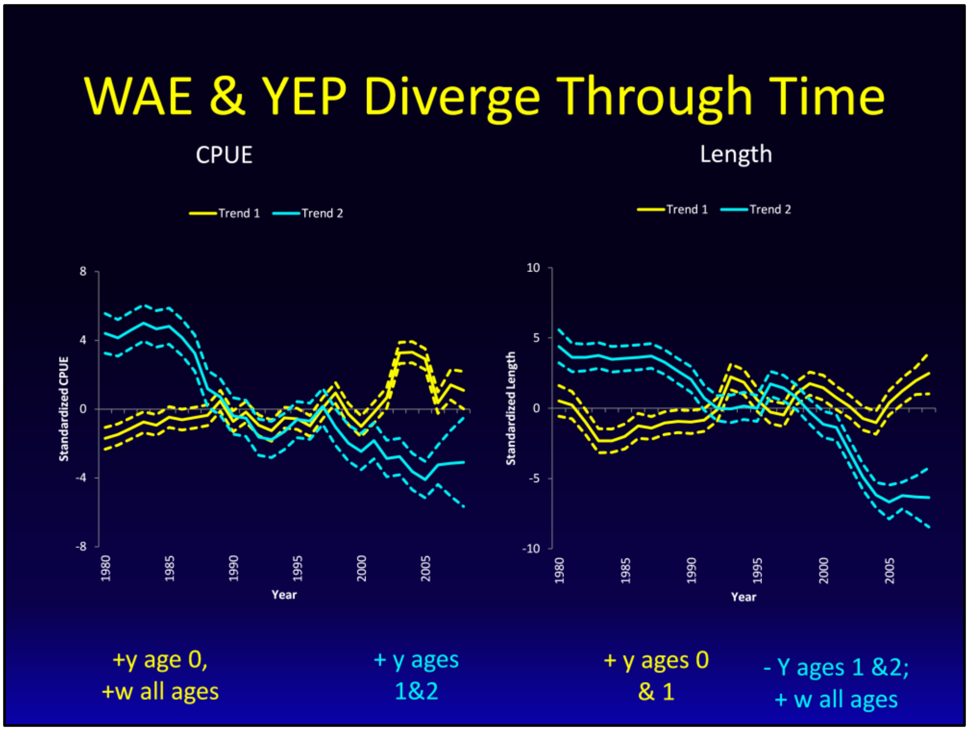
A 2-axis matrix was selected as the best matrix to describe variability in the data. The first axis explains 7% of the variability in the fish community while the second axis explains 85% of the variance in the data. As you can see, the second axis separates the 70s and 80s from the 90s-00s. We ran Spearman rank correlations between the axes' scores and the fish. White bass were positively related to axis 1 while alewife, bluntnose minnow, goldfish, largemouth bass, rock bass, rainbow smelt and spottail shiner were negatively related to this axis. Anything to the right of the y-axis would therefore have higher catches of white bass while those to the left will have higher catches of species like alewives. Black crappie, rainbow smelt, pumpkinseed and yellow perch were significantly correlated with axis 2, so their catches were higher in the 1970s than present. Bluntnose minnow, carp, freshwater drum, lake whitefish, logperch, mimic shiner, white sucker, rock bass, quillback, smallmouth bass, trout-perch, walleye, white bass, and white perch were negatively related to axis 2, and therefore were found in greater numbers in the 90s and 00s.



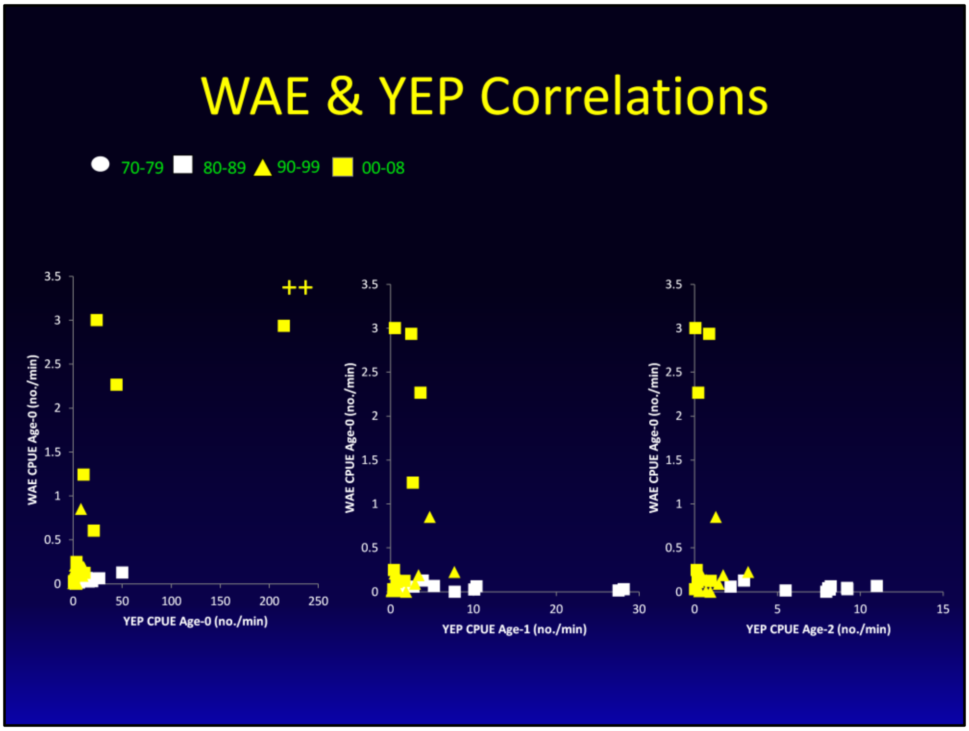
Overall, fish community has improved (more species and more abundant). DFA and NMDS, with their different assumptions and different species included, still show that most species have increased in CPUE, which gives us more confidence in our conclusions. However, there appears to be a drop in richness and abundance since around 2000, something managers should continue to monitor.



Specifically, there has been a lot of concern over walleye and yellow perch dynamics in Saginaw Bay.

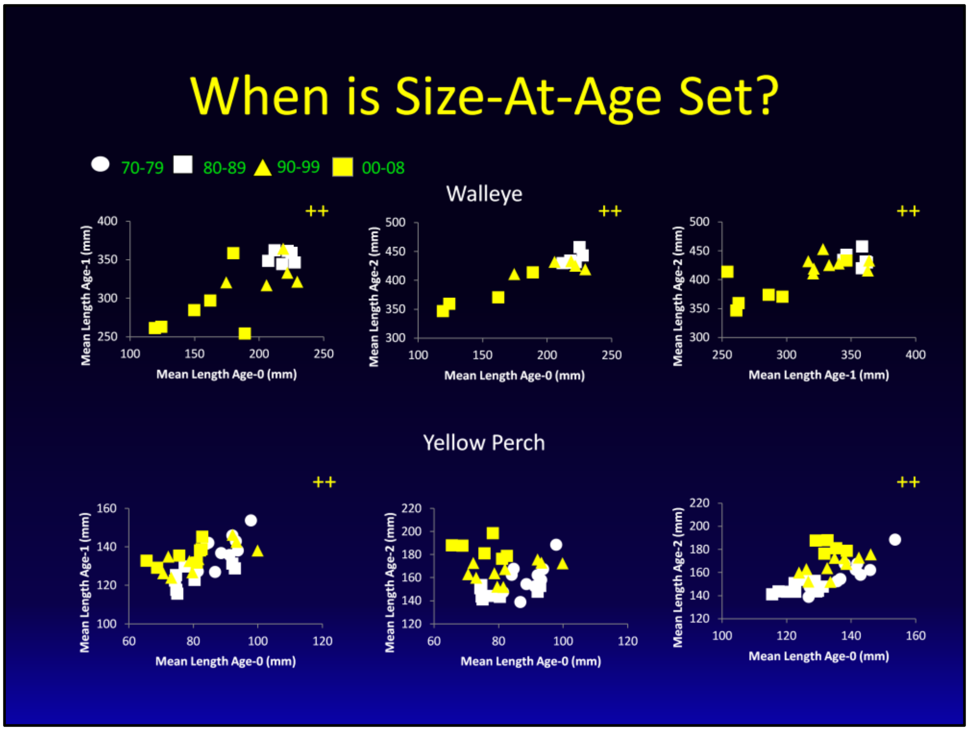


Results of DFA for CPUE (Left) and length (Right) of combined walleye and yellow perch ages 0-2. Both were explained by 2 trends. For the CPUE model, the first trend was increasing (with a slight decline after 2004) and was positively related to age-0 yellow perch and age0-2 walleye. The second trend was one of decreasing CPUE and was positively related to yellow perch ages 1-2. For length-at-age, the first trend fluctuated around the mean but generally increased, especially at the end of the time series. This trend was followed by age 0-1 yellow perch. The second trend was one of decreasing size-at-age and was followed by walleye ages 0-2 and was negatively associated with yellow perch ages 1-2. This analysis suggests the following: 1) walleye and yellow perch are diverging through time in both CPUE and mean size-at-age, 2) recruitment and size-at-age is set at age-0 for walleye but not till age-1 for yellow perch, and 3) there might be evidence of density-dependent growth as CPUE and mean size-at-age are trending oppositely for both species.

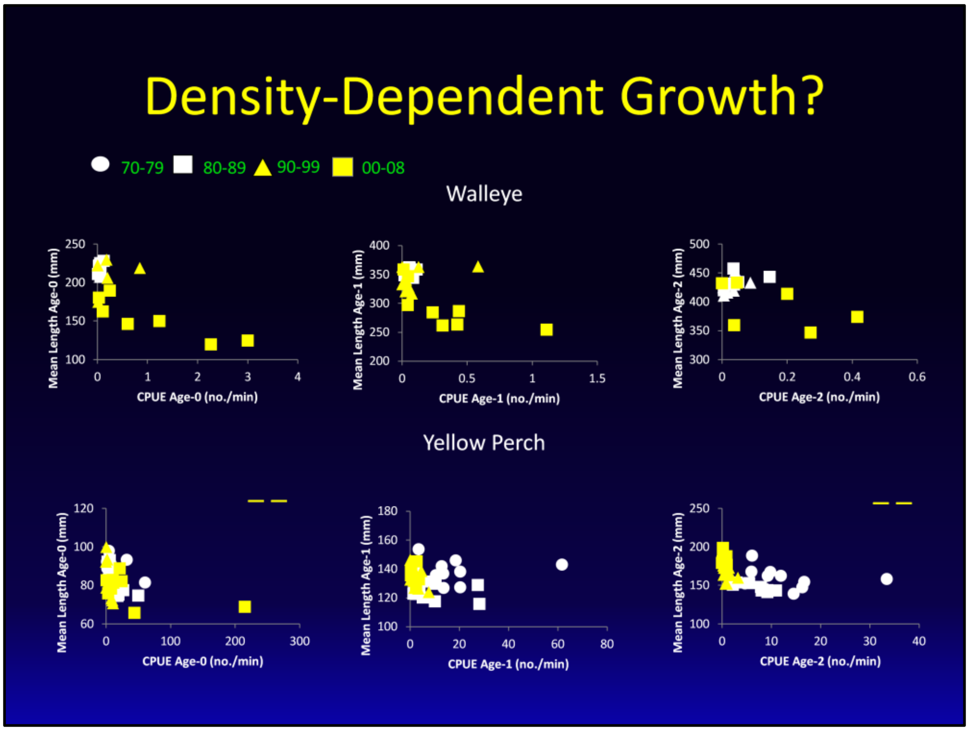


We used correlation analysis to see if there was evidence for the 3 conclusions listed in the previous slide. These graphs show the relationship among yellow perch (ages 0-2) and age-0 walleye. ++ indicates a significant positive relationship (based on Spearman's rank correlation; data is NOT plotted as ranks). There is a significant relationship between age-0 walleye and age-0 yellow perch but no relationship between age-0 walleye and age-1&2 yellow perch.

These figures show when recruitment is set. The top panel shows correlations among walleye cohorts. Age-0 walleye are correlated to age-1 and age-2 walleye the following two years and age-1 walleye are correlated with age-2 walleye. This suggests that recruitment is set for walleye by fall age-0. For yellow perch (bottom panel) there are positive correlations between age-0 yellow perch and age-1 yellow perch, and between age-1 and age-2 yellow perch, but there is not relationship between age-0 and age-2 yellow perch. The setting of recruitment is less clear for yellow perch, and we suggest that it is not set until fall age-1.



This slide is the same as the previous one except this slide contains panels for correlations between size-at-age for walleye and yellow perch. The results are similar to CPUE and suggest that size-at-age is set for walleye at age-0 and likely not set until age-1 for yellow perch.



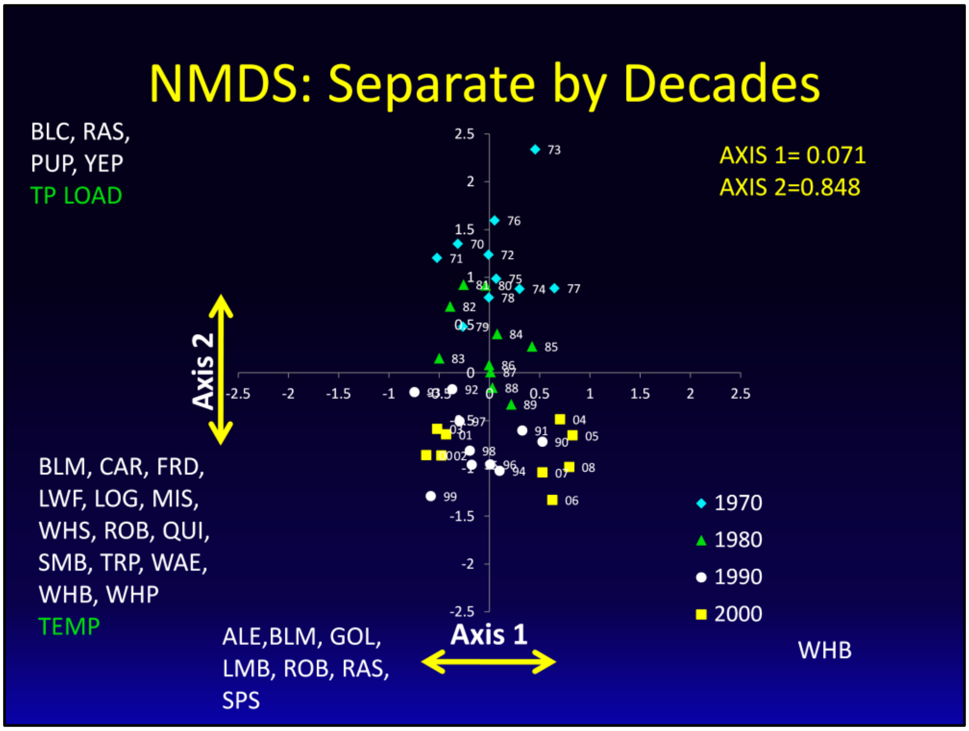
DFA results suggested that there would be evidence for density-dependent growth for both walleye and yellow perch. However, there were no significant correlations between ages for walleye, although there does appear to be a negative relationship between CPUE and mean length for ages 0, 1 and 2 (left to right). This is not an unexpected result as stocking and especially the large increase in CPUE in 2003 following the collapse of alewives and the large increase in natural recruitment should lead to declines in growth rates. For yellow perch, there were negative relationships for age-0 and age-2 fish, but not for age-1 fish, suggesting density-dependent growth for these age classes.

Conclusions

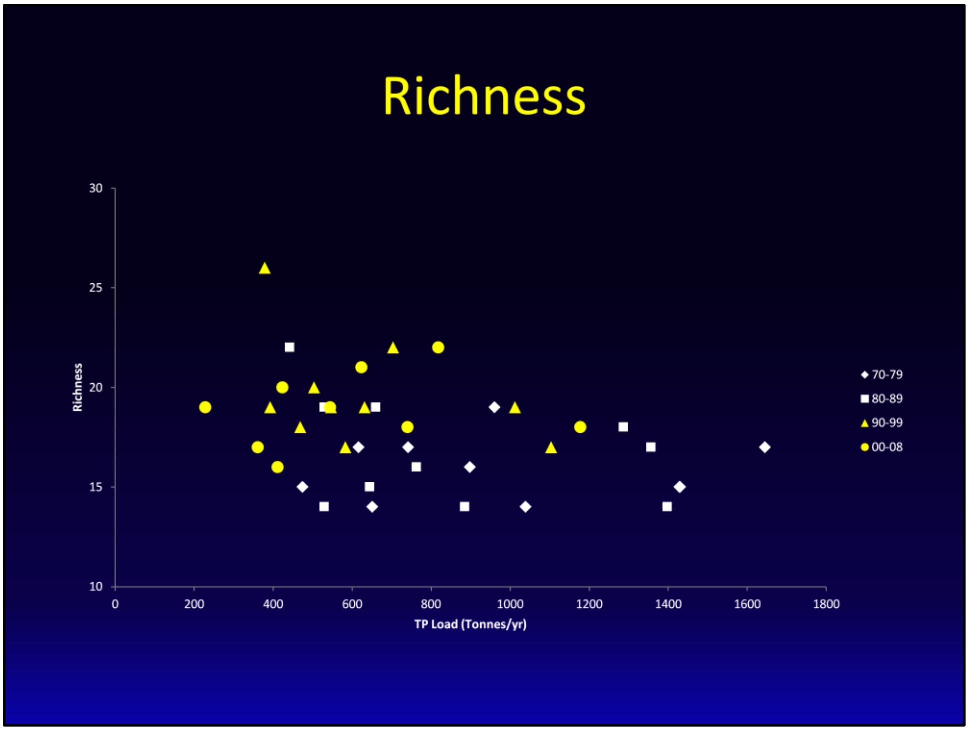
- Walleye and yellow perch trend separately
  - Walleye increasing
  - Yellow perch decreasing
- Recruitment & size-at-age
  - Set by age-0 for walleye
  - Set by age-1 for yellow perch
- Density-dependent growth
  - Yellow perch
  - Walleye?

Summary of findings of DFA and Spearman rank correlations.

Future directions for this analysis include incorporating some environmental variables that might be driving the patterns we described throughout this presentation. The next two slides show how we might apply some of these potential drivers.



This is the NMDS slide seen previously. We correlated some environmental variables with the axes derived from the NMDS, including TP load and annual flow of the Saginaw River from Cha et al. 2010 and mean temp and mean secchi depth from the fall trawl surveys. TP load was positively related to axis 2, so loads were higher in the 70s. Fall temperature was negatively related to axis 2 so temp was higher in the 90s and 2000s. However, this increase might be due to the timing of trawls and is likely not a very good indicator of conditions experienced by the fish community. We are currently working on getting data to look at more meaningful metrics (i.e., growing degree days, overwinter severity).



The relationship between total species richness and TP load of the Saginaw River (Cha et al. 2010). This is a significantly negative relationship (rho =-0.38).